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INTRODUCTION

Globally, the ever-expanding and exponentially increasing human population has led to a growing demand for energy, food, water, and other various resources. As technological advancements in agricultural practices, energy development, and harvesting of natural resources continue, the magnitude, frequency, and distribution in changing land-use practices increase precipitously (DeFries et al. 2004; Patz et al. 2004; Foley et al. 2005). These environmental stressors have led to drastic alterations to habitat configuration and composition, ultimately leading to degradation of key ecosystem functions and a reduction in valuable ecosystem services. Although these environmental impacts have direct and indirect long-term consequences for human populations (DeFries et al. 2004; Patz et al. 2004; Foley et al. 2005), the immediate sweeping effects of habitat loss and degradation have significantly contributed to widespread species decline (Groombridge 1992; Lindenmayer & Fischer 2006; Thuiller 2007).

In Conservation Biology, management for species and their respective habitats is a fundamental component in mitigating population declines and restoring ecosystem function in highly altered landscapes (Fahrig 1997). Land-sparing conservation techniques – measures that protect existing habitat through easements or habitat restoration practices – can help provide critical resources that allow species to maintain their life history strategies. The Conservation Reserve Program (CRP) is one example of a widely implemented conservation practice in the United States, which restores lands currently in crop production to a grassland vegetation community. The first establishment of CRP in the 1985 Farm Bill was intended to help manage supply and stabilize volatile commodity markets. However, although they were initially unintended, numerous other ecosystem services were provided by CRP, including reduced erosion on highly erodible lands, and increased water quality and quantity. The CRP program has often been regarded as the most successful conservation practice over the course of its history, particularly for grassland and upland game species (Peterjohn 2003; Giudice & Haroldson 2007; Nielson et al. 2008; Herkert 2009). However, even when conservation practices are implemented and are intended to restore or enhance habitat conditions for a suite of species, the success of those activities can vary widely (McCoy et al. 1999; Rodgers 1999; Rahmig et al. 2008) and may be constrained by the surrounding landscape (Jorgensen 2012; Jorgensen et al. 2014*b*).

Certainly there are many explanations and examples attributed to varying levels of management success, but one explanation may be that a species forms habitat selection decisions over a spatial scale beyond the boundaries of the management area. While habitat selection theory predicts that a species will select the best available habitat based on a set of biological cues indicative of resource availability (Hilden 1965), it is widely believed that these decisions are formed over spatial scales relevant to the species' body size or mobility (Peters 1983; Rosenzweig 1991; Holling 1992), particularly in terrestrial mammals. As for long-distance migratory species, such as neotropical migrant birds, the process of selecting suitable habitat may begin at much larger spatial scales, using a hierarchical assessment of landscape configuration, local habitat conditions, and micro-habitat composition (Hutto 1985; Wiens 1994; Stephens et al. 2003). The significance of the landscape composition and configuration component in a hierarchical selection process may outweigh the importance of local habitat quality and may explain the variation in management success across a wide range of conservation programs. This notion is widely supported in the literature (Saab 1999; Best et al. 2001; Stephens et al. 2003; Holland et al. 2004; Cunningham & Johnson 2006). Still, even in instances where we have identified the mechanisms constraining management success, we are often left with the questions: Where do we manage? What are we managing for, and what takes priority? This underlying dilemma in managing for species and their respective habitat increases as a function of resource availability and the number of stakeholders and conservation agencies involved in the decision-making process.

Identifying where to manage, and for which species or suites of species, is a challenge that has been tackled numerous times by conservation agencies and research projects in recent history. For example, the notion of a "surrogate species," -- a representative species that serves as an indicator of landscape habitat and system conditions characteristic of species using similar habitats (Caro 2010) -- was recently adopted as part of the U.S. Fish and Wildlife Service's Strategic Habitat Conservation framework (U.S. Fish and Wildlife Service, 2012, Unpublished Report). Once a surrogate species is identified, a habitat manager is able, by managing for that species' habitat, to also meet the resource requirements of the other species that use similar habitat types (Caro et al. 2004; Fraser et al. 2008; Mistry et al. 2008; Saha & Haldar 2009; Lindenmayer et al. 2014). Likewise, a variety of methods of using spatially explicit habitat models to predict species occurrence and distribution are continually being developed (Franklin 2009). Species distribution models are applications of ecological niche theory, utilizing spatially explicit climate, topographic, and landscape variables to predict species occurrence or abundance (Franklin 1995; Guisan & Zimmermann 2000; Hirzel & Le Lay 2008; Fletcher et al. 2010). In addition, species distribution models allow extrapolation of relatively limited field samples from finite study areas to the entire potential range of a species. Once a predictive distribution is produced, the species distribution model can be applied to a number of applications in the conservation field. For instance, species distribution models can be used to predict changes in species distributions resulting from climate change (e.g., Thomas et al. 2004; Hannah & Phillips 2004), to identify how species respond to changes in habitat connectivity (e.g., McRae and Beier 2007), to forecast biological invasions (e.g., Peterson 2003; Ficetola et al. 2007; Zhu et al. 2007), to detect biological hotspots (e.g., Midgley et al. 2002), to discover new species' ranges (e.g., Carroll et al. 2001; Ponder et al. 2001), and to predict species responses to changes in land use (e.g., Donald et al. 2002; Niemuth et al. 2007).

Although there are ever-increasing ways to identify the species for which to manage and where to manage them, we still often struggle with the question of which species or conservation objectives take priority over others. These multiple objectives established by stakeholders can be effectively addressed and optimized by using a Decision Support System (DSS) to help make informed decisions. A DSS is a computer-based information system that is used by decision makers to compile important information from personal knowledge, data, and models to identify solutions to problems and make informed decisions (Jankowski & Richard 1994). Here we describe the construction and implementation of a Geographic Information System (GIS) -based DSS intended to help prioritize focus regions for establishing conservation easements or other conservation practices in northeastern Nebraska, U.S.A. In addition, we demonstrate how we can maximize the likelihood of addressing a multitude of stakeholder values by identifying areas within the focus region where multiple habitat or conservation objectives can be achieved. By integrating existing species distribution models and a spatially explicit model of soil erodibility into a set of decision support tools, we can furthermore direct conservation actions to specific regions that are expected to provide the greatest return on our conservation efforts.

METHODS

Conservation Focus Region

A total of eight counties (Antelope, Brown, Boyd, Holt, Keya Paha, Knox, Peirce and Rock counties) in the northern and northeastern regions in Nebraska were selected as the priority conservation focus area for our modeling efforts and conservation delivery. These counties encompass several Biologically Unique Landscapes as defined in the Nebraska Natural Legacy Project (Schneider et al. 2011), including the Elkhorn Confluence, Keya Paha, Lower Niobrara, Middle Niobrara, Verdigre-Bazile, and Willow Creek Prairies. Although these Biologically Unique Landscapes provide critical habitat to a variety of species and are often considered biodiversity hotspots by the state (Schneider et al. 2011), the entire focus area has seen accelerated grassland conversion and habitat fragmentation in recent history. Strategically placed and effective conservation measures are therefore needed to help reduce habitat fragmentation and species loss within the region. To increase the utility of our modeling efforts, we added an additional 15 counties (Boone, Blaine, Burt, Cedar, Cherry, Cuming, Dakota, Dixon, Garfield, Loup, Madison, Stanton, Thurston, Wayne, and Wheeler counties) surrounding the priority focus area, which expanded the focus area to the entire northeastern quarter of Nebraska.

Data Compilation

In order to construct a tool useful in predicting and identifying regions best suited for achieving multiple conservation objectives, we compiled a series of existing distribution models for seven priority species that have established populations within the northeastern conservation focal region (Table 1). Two of the seven priority species, the American burying beetle (*Nicrophorus americanus*) and the Greater Prairie-Chicken (*Tympanuchus cupido*), are identified as at-risk species in Nebraska, according to the Nebraska Natural Legacy Project (i.e., Tier I species; Schneider et al. 2011). We also included the Ring-necked Pheasant (*Phasianus colchicus*), a socially and economically important game species in Nebraska, as one of the seven priority species. The remaining four priority species were the Bobolink (*Dolichonyx oryzivorus*), Field Sparrow (*Spizella pusilla*), Grasshopper Sparrow (*Ammodramus savannarum*), and Western Meadowlark (*Sturnella neglecta*), three of which have experienced significant population declines throughout the United States during the last half-century (Sauer et al. 2014). Biologically speaking, the seven selected species represent a variety of different macro- and micro-habitat requirements (e.g., Peterjohn & Rice 1991; Bollinger & Gavin 1992; Vickery 1996; Carey et al. 2008; Davis & Lanyon 2008; Jurzenski et al. 2014; Jorgensen et al. 2014*a*), and according to their species distribution models, they potentially form habitat decisions using biological cues identified over a range of spatial scales (e.g., 200-m radius [Western Meadowlark] to 5000-m radius [Ring-necked Pheasant]; Jorgensen et al. 2013; Jorgensen et al. 2014*b*). All species distribution models have varying levels of predictability and are modeled across a number of spatial scales (Table 1).

With the exception of the Ring-necked Pheasant, (for which there is insufficient survey data), the distribution models for the remaining species selected for the Northeast DSS were created using binomial generalized linear or generalized linear mixed models (Zuur et al. 2007) to predict species occurrence throughout level II and level III ecoregions in Nebraska (defined by the Environmental Protection Agency) or across the entire state. The Ring-necked Pheasant species distribution model was created for the entire state of Nebraska using an N-mixture model (Royle 2004) to model species abundance (Jorgensen 2012; Jorgensen et al. 2014*b*). There has been a significant sampling effort in the northeast portion of Nebraska to understand the distribution of the American burying beetle and Greater Prairie-Chicken. As a result, separate species distribution models could be created for these species within the Sandhills, as well as in the Loess Plains ecoregions (Bishop et al. 2012, Jorgensen et al. 2014*a*, Jurzenski et al. 2014). The species distribution models for the four passeriformes (Bobolink, Field Sparrow, Grasshopper Sparrow, and Western Meadowlark) were developed from the Breeding Bird Survey data and therefore completed at a statewide scale (Jorgensen et al. 2013).

All species distribution models used in the modeling process were constructed using land cover, topography, and climate variables in a GIS. The scales at which the models were developed were defined according to the spatial scales relevant to the species, based on life history strategies or life cycle stage (i.e., breeding phase for Bobolink, Field Sparrow, Grasshopper Sparrow, Ring-necked Pheasant, and Western Meadowlark), recapture distance (American burying beetle), or nesting distance from the lek (Greater Prairie-Chicken). The spatial scales that were used were not consistent across all seven species (Table 1).

Table 1. List of seven species distribution models used in creating the Northeastern Decision Support System for Nebraska.

Model	**Type/Spatial Scale**	**Accuracy**	**Source**
American burying beetle (Eastern)	Probability of Occurrence/800-m radius	AUC Value= 0.79	Jorgensen, C.F., McPherron, M., Jurzenski, J.D., Grosse, R., Bishop, A., Fritz, M., Harms, R., Koch, M., and Hoback, W.W. 2014. Nebraska's American burying beetle Species Distribution Model for the Loess Prairie ecosystem. Rainwater Basin Joint Venture Report, Grand Island, Nebraska, U.S.A.
American burying beetle (Sandhills)	Probability of Occurrence/800-m radius	AUC Value= 0.89	Jurzenski, J.D., Jorgensen, C.F., Bishop, A., Grosse, R., Riens, J., and Hoback, W.W. 2014. Identifying priority conservation areas for the American burying beetle, *Nicrophorus americanus* (Coleoptera: Silphidae), a habitat generalist. *Systematics and Biodiversity*
Bobolink	Probability of Occurrence/200-m radius	AUC Value= 0.81	Jorgensen, C.F., Bishop, A.A., Dudley, T., Grosse, R. and Nugent, E. 2013. Conservation of avian resources through species distribution models and strategic habitat conservation. Rainwater Basin Joint Venture Report, Grand Island, NE, U.S.A.
Field Sparrow	Probability of Occurrence/800-m radius	AUC Value= 0.86	Jorgensen, C.F., Bishop, A.A., Dudley, T., Grosse, R. and Nugent, E. 2013. Conservation of avian resources through species distribution models and strategic habitat conservation. Rainwater Basin Joint Venture Report, Grand Island, NE, U.S.A.
Grasshopper Sparrow	Probability of Occurrence/800-m radius	AUC Value= 0.76	Jorgensen, C.F., Bishop, A.A., Dudley, T., Grosse, R. and Nugent, E. 2013. Conservation of avian resources through species distribution models and strategic habitat conservation. Rainwater Basin Joint Venture Report, Grand Island, NE, U.S.A.
Greater Prairie-Chicken (Eastern)	Probability of Occurrence/1600-m radius	AUC Value= 0.83	Bishop, A., Grosse, R., Nugent, E., and Jorgensen, C. 2012. Assessing species probability of occurrence and distribution for Greater Prairie-Chicken, Sharp-tailed Grouse, and Long-billed Curlew throughout Nebraska. Rainwater Basin Joint Venture Report, Grand Island, NE, U.S.A.
Greater Prairie-Chicken (Sandhills)	Probability of Occurrence/5000-m radius	AUC Value= 0.93	Bishop, A., Grosse, R., Nugent, E., and Jorgensen, C. 2012. Assessing species probability of occurrence and distribution for Greater Prairie-Chicken, Sharp-tailed Grouse, and Long-billed Curlew throughout Nebraska. Rainwater Basin Joint Venture Report, Grand Island, NE, U.S.A.
Ring-necked Pheasant	Abundance/5000-m radius	Sperman's r_s = 0.64	Jorgensen, C.F. 2012. Assessing local and landscape constraints on habitat management for grassland and upland birds. Dissertations & Theses in Natural Resources. Paper 60.
Western Meadowlark	Probability of Occurrence/200-m radius	AUC Value= 0.85	Jorgensen, C.F., Bishop, A.A., Dudley, T., Grosse, R. and Nugent, E. 2013. Conservation of avian resources through species distribution models and strategic habitat conservation. Rainwater Basin Joint Venture Report, Grand Island, NE, U.S.A.

In order to identify areas where species are most likely to occur within the northeastern focus region, we set the required specificity for each probability of occurrence model and used an optimal threshold value approach to convert probability of occurrence values to predicted presence-absence (Freeman & Moisen 2008). For each species, we obtained a testing dataset of known presences or absences at survey locations by using either a k-fold cross validation approach (Verbyla & Litvaitis, 1989; Geisser, 1993; Kohavi, 1995), which utilizes all of the existing survey data (e.g., Breeding Bird Survey data) used to create the species distribution model, or a testing dataset that was set aside prior to creating the models. These testing datasets were used to identify the predicted probability of occurrence value where 95% of the actual survey locations known to be "absent" fell below the threshold (Table 1; Freeman & Moisen 2008). Any areas within the species distribution models where the probability of occurrence values ranged above the required specificity threshold were reclassified to "presence," and those below were reclassified as "absence." Reclassifying the species distribution models by this methodology is a conservative approach that allowed us to identify where each species is most likely to occur within the conservation focus region based on the surrounding landscape composition (Freeman & Moisen 2008). Furthermore, this approach also helped minimize our chances of inflating the predicted presences by over declaring true species absences as predicted presences.

Since the Ring-necked Pheasant species distribution model was developed to predict abundance rather than probability of occurrence, we took an alternative approach to reclassifying the distribution model for this species. We grouped predicted abundance values into four bins, using an equal interval approach in a GIS. Each of the four categories represented 25% of the range of predicted abundance values in the original Ring-necked Pheasant species distribution model. The new values in the model ranged from one to four, based on the four reclassified categories. Areas that were assigned a value of four within the reclassified spatially explicit model represented the highest 25% abundance values within the conservation focus region. Areas assigned a value of one represented the lowest 25% abundance values.

Given that the Northeast DSS may be used to target areas suited for specific grassland conservation programs, which would not only provide valuable habitat to grassland species but also reduce soil erosion, we also developed a tool to identify tracts of land within the conservation focus area that contain highly erodible soils. Historically, soil erosion has consistently been an issue in regions that use conventional cropping practices. Consequently, in the last century, various federal and state programs have been established to offer landowners incentives to reduce soil erosion by taking lands that contain highly erodible soils out of production and converting them to grasslands (e.g.,1956 Soil Bank program, the 1985 Conservation Reserve Program; Cain & Lovejoy 2004; USDA – NRCS 2012).

To quantify potential wind and water erosion, a highly erodible soils index was developed (Figure 1). In cooperation with the U.S. Department of Agriculture's Natural Resources Conservation Service, we constructed a Wind and Water Erodibility Index using the Soil Survey Geographic (SSURGO) database (U.S. Department of Agriculture–Natural Resources Conservation Service 2011). We used a modified version of the Universal Soil Loss Equation (USLE) to produce erodibility indices for wind and water (following methods outlined in Woodruff & Siddoway 1965; U.S. Department of Agriculture 1978), and reclassified the data into a Highly Erodible Soils Index by taking raster values greater than 8 tons/acre/year in both indices and reclassifying them to a value of 1, and everything else to a value of 0 (pers. comm. Dan Shurtliff, U.S. Department of Agriculture – Natural Resources Conservation Service). We quantified the percentage of highly erodible soil acres within each field boundary delineated in the Farm Service Agency's Common Land Unit (CLU) GIS dataset. Each parcel with > 50% erodible soils was assigned a value of 100; parcels with 33-50% were assigned a value of 75; properties with 5-33% highly erodible soils were assigned a value of 50; and properties with less than 5% erodible soils were assigned a value of 25 (Note: erodible soil groupings and values are subject to change based on stakeholder needs and objectives). These final values were used in conjunction with weights assigned to the Highly Erodible Soils Factor in the DSS, establishing priority to land units containing high proportions of erodible soils (Table 2).

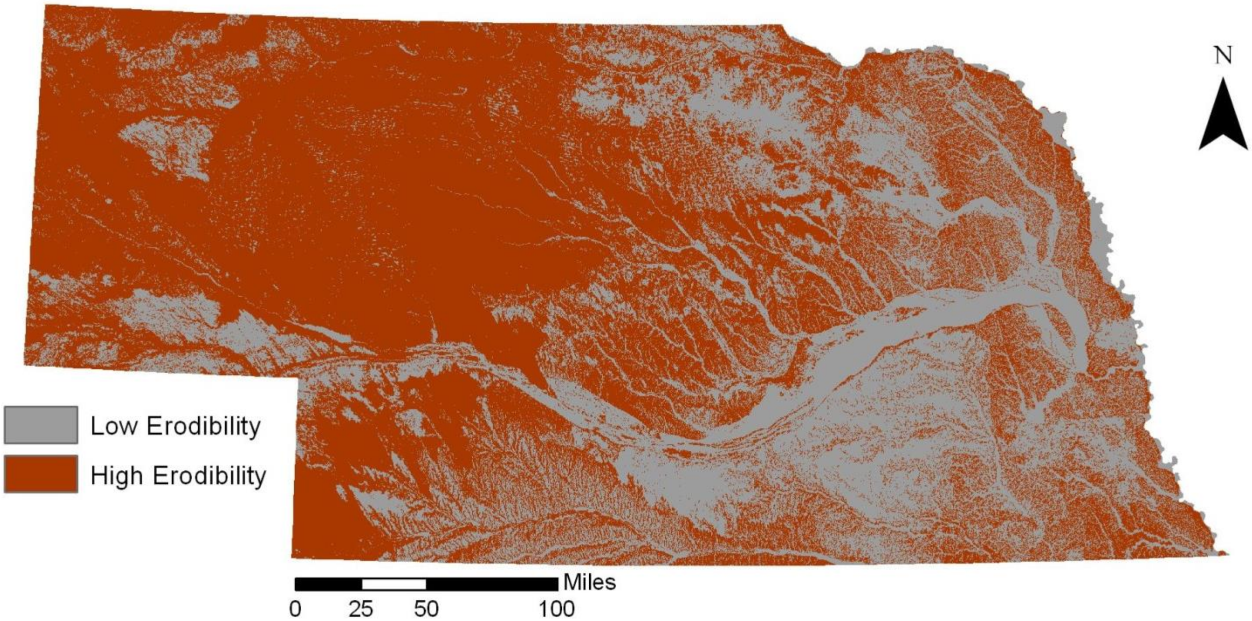

Figure 1. The Highly Erodible Soil Index was constructed by reclassifying Water Erodibility and Wind Erodibility Indices for Nebraska, where any values over 8 were reclassified as highly erodible soils. Areas containing highly erodible soils were weighted according to the percentage of erodible soils contained within the land unit. Areas with >50% of erodible soils were assigned a value 100; 33-50% were assigned a value of 75; 5-33% were assigned a value of 50; and areas with < 5% erodible soils were assigned a value of 25. The assigned values prioritized grassland-dominant crop incentives to land units with higher percentages of erodible soils.

Decision Support System Criteria

To create a useful DSS, several outputs were developed. The contemporary assessment tool identifies areas currently capable of supporting priority species, while the scenario assessment predicts where future conversions of cropland to grassland could have the greatest impact on the suite of priority species. While the contemporary tool focuses on identifying regions that can support species populations and is suited for local habitat enhancement projects based on the present landscape composition and configuration, the scenario-based tool assumes 30% of the existing row crop in the surrounding landscape is converted to grassland. A key assumption in the scenario-based DSS is that there are not significant changes in distribution and abundance of habitat and that habitat quality is maintained throughout the region. In addition, we assumed that the areas identified as having the highest likelihood of increasing species occurrence or abundance will continue to be priority areas regardless of whether less than 30% of the existing row crop is converted to grassland. This last assumption is based on sensitivity analysis performed using the species distribution models prior to finalizing the scenario-based DSS. The sensitivity analysis highlighted that even with less than 30% conversion, the conservation hotspots remained geographically consistent.

By using scenario planning, we are able to identify potential regions where policy makers and habitat managers have the opportunity to meet all of their objectives, assuming that new grassland is established in the landscape. Once each scenario-based species distribution model was developed, we subtracted the row crop-to-grassland distribution models from the contemporary models (Figure 2). This allows us to identify where we would expect to see new species populations persist, based on the future landscape composition and configuration. We developed scenario-based distribution models for six of the seven priority species, excluding the American burying beetle since the statistical model for that species did not indicate that the available grassland or row crop agriculture in the landscape explained species occurrence.

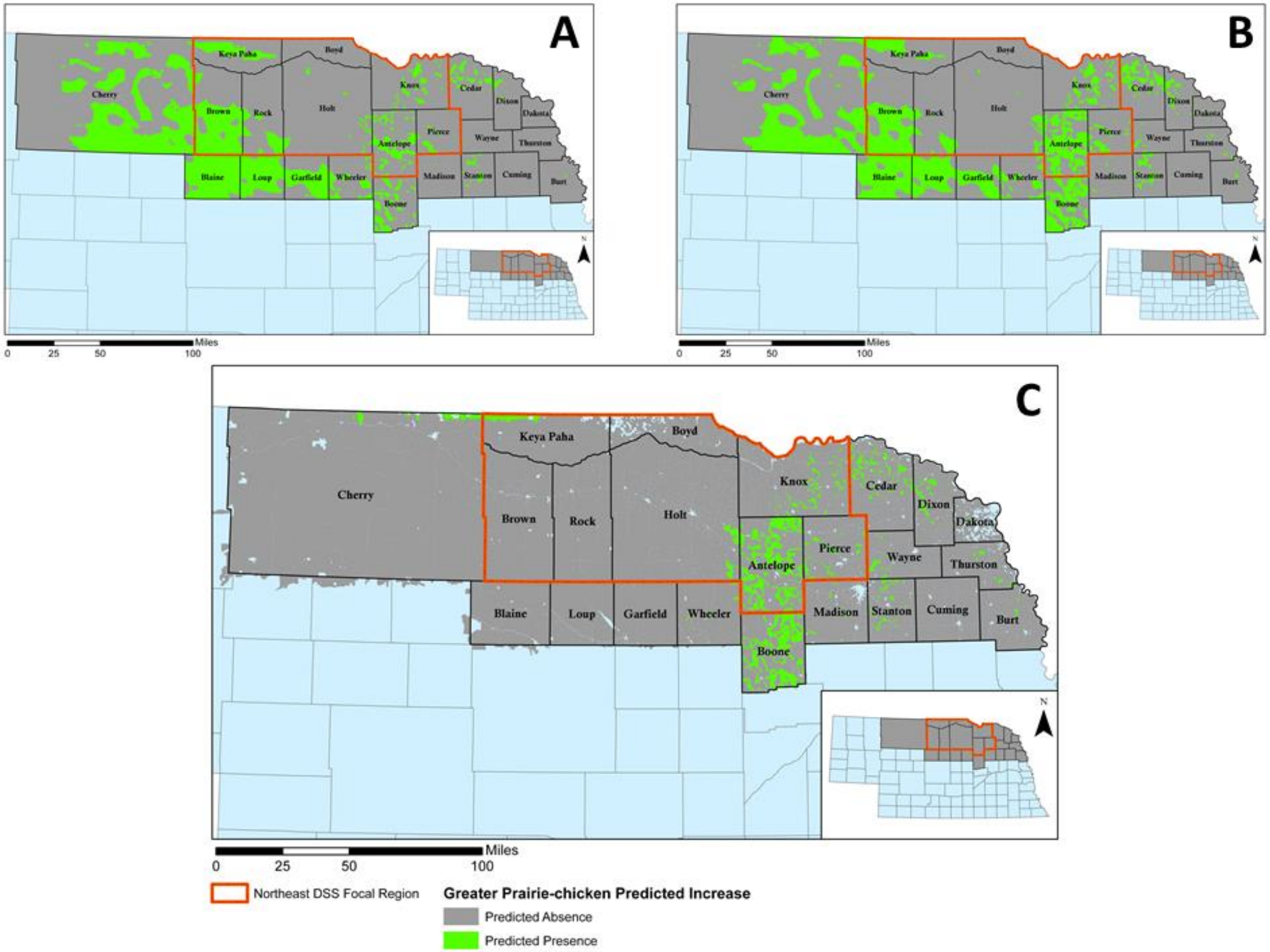

Figure 2. An example of a contemporary species model (A, Greater Prairie-Chicken) of predicted presence-absence for the northeastern conservation focal region, and the scenario-based species model (B) after 30% row crop in the surrounding landscape is converted to grassland. The scenario-based model (B) is subtracted from the contemporary (A) to identify new tracts of land that are most likely to support the species after row crop conversion (C).

A total of five factors were included in the contemporary DSS, and four were incorporated in the scenario-based tool. Since the four passerines (Bobolink, Field Sparrow, Grasshopper Sparrow, and Western Meadowlark) all have similar life-history strategies and respond to habitat cues across similar spatial scales (Jorgensen et al. 2013), we grouped the four species distribution models as an indication of species richness. The other four factors incorporated in the contemporary DSS included the American burying beetle, Ring-necked Pheasant, and Greater Prairie-Chicken models, in addition to the highly erodible soils index (Table 2). All but the American burying beetle were included as factors in the scenario-based DSS (Table 3). We established weighting criteria for each factor to appropriately weight each factor in the DSS contemporary tool. A set of values were assigned to each factor in the DSS, based on the level of ecological response or importance. We also weighted each factor as a demonstration of how DSS values can change based on conservation priority and management goals (Note: weights are subject to change based on future stakeholder objectives; Tables 2 & 3). The sum of all of the factor weights calculated to 1.0. It is important to note, however, that factor weights are allowed to change and are dependent on stakeholder priorities, management objectives, and the specific landscapes being considered for habitat management.

Values and weights were extracted to a CLU spatial dataset using a GIS, where each boundary within the dataset is the smallest unit of land that has a permanent, contiguous boundary, or contains a common land cover, owner or producer (U.S. Department of Agriculture – Farm Service Agency 2013). We multiplied each factor's value by its associated weight (Tables 2 & 3) and summed all products together to form a final weighted value associated with each land unit in the DSS.

Table 2. The criteria, description and weights of five factors included in the contemporary Northeast Decision Support System for Nebraska.

Factor	Criteria	Description	Value	Weight
American burying beetle Predicted Presence/Absence	Predicted Present	Predicted presence - based on < 5% of predicted absences were misclassified	100	0.25
	Predicted Absent	Predicted absence - based on < 5% of predicted absences were misclassified	0	
Greater Prairie-Chicken Predicted Presence/Absence	Predicted Present	Predicted presence - based on < 5% of predicted absences were misclassified	100	0.25
	Predicted Absent	Predicted absence - based on < 5% of predicted absences were misclassified	0	
Highly Erodible Soils[1] [1]Erodibility Index Values >= 8	Maximum	> 50% erodible soils on property	100	0.10
	High	33-50% erodible soils on property	75	
	Medium	5-33% erodible soils on property	50	
	Low	<5% erodible soils on property	25	
Grassland Bird Species Richness[2] [2]Includes Bobolink, Grasshopper Sparrow, Field Sparrow, and Western Meadowlark predicted presence/absence	Maximum	4 of 4 species present	100	0.15
	High	3 of 4 species present	75	
	Medium	2 of 4 species present	50	
	Low	1 of 4 species present	25	
Ring-necked Pheasant Abundance	Maximum	Top 25% of predicted values	100	0.25
	High	Upper-middle 25% of predicted values	75	
	Medium	Lower-middle 25% of predicted values	50	
	Low	Bottom 25% of predicted values	25	
			Total Weight =	1.00

Table 3. The criteria, description and weights of four factors included in the scenario-based Northeast Decision Support System for Nebraska.

Factor	Criteria	Description	Value	Weight
Greater Prairie-Chicken Predicted Presence/Absence	Predicted Present	Predected presence - based on < 5% of predicted absences were misclassified	100	0.25
	Predicted Absent	Predected absence - based on < 5% of predicted absences were misclassified	0	
Highly Erodible Soils[1] [1]Erodibility Index Values >= 8	Maximum	> 50% erodible soils on property	100	0.25
	High	33-50% erodible soils on property	75	
	Medium	5-33% erodible soils on property	50	
	Low	<5% erodible soils on property	25	
Grassland Bird Species Richness[2] [2]Includes Bobolink, Grasshopper Sparrow, Field Sparrow, and Western Meadowlark predicted presence/absence	Maximum	4 of 4 species present	100	0.25
	High	3 of 4 species present	75	
	Medium	2 of 4 species present	50	
	Low	1 of 4 species present	25	
Ring-necked Pheasant Abundance	Maximum	Top 25% of predicted values	100	0.25
	High	Upper-middle 25% of predicted values	75	
	Medium	Lower-middle 25% of predicted values	50	
	Low	Bottom 25% of predicted values	25	
			Total Weight =	1.00

RESULTS

The contemporary Northeast Decision Support System had values ranging from 0 to 100 (Figure 3), meaning that, based on the current conservation objectives and weights (Table 2), there are areas within the northeastern focus area where policy makers and habitat managers can achieve none or all of their species-management and conservation objectives. Blaine, Brown, Cherry, Keya Paha, Rock, and Loup counties have the highest likelihood of achieving all conservation objectives, assuming all local habitat quality is equal.

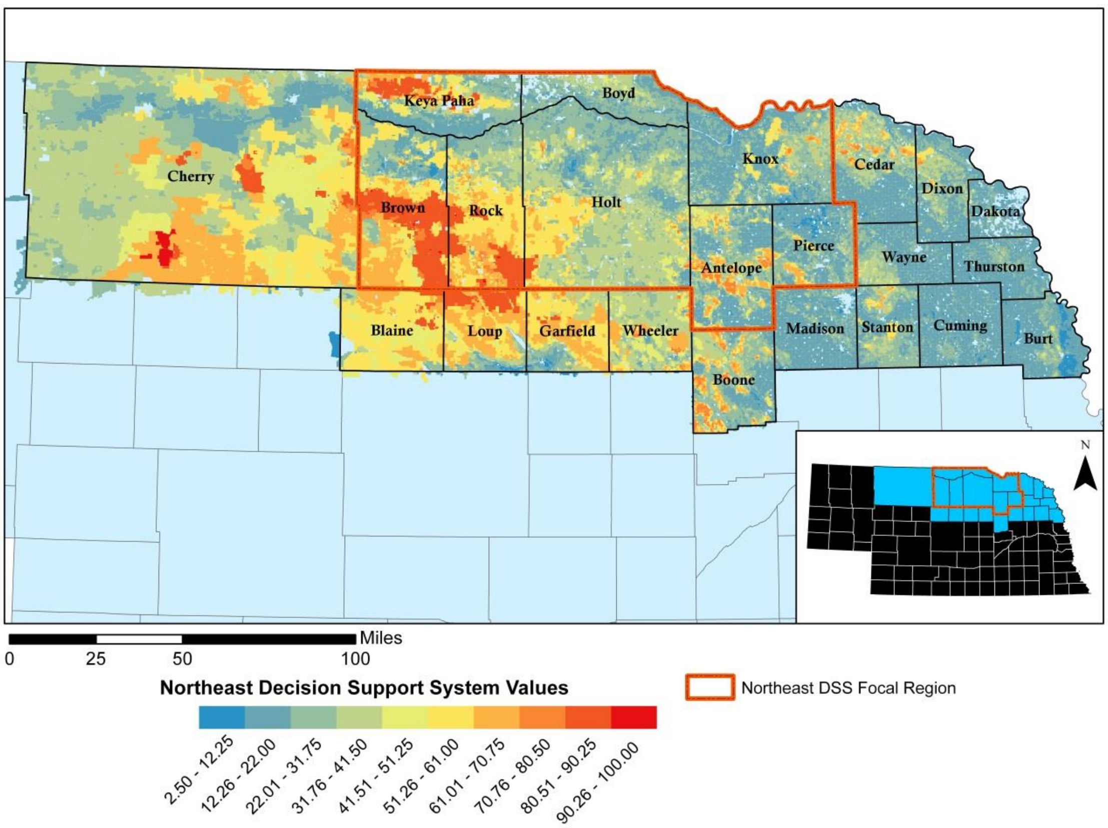

Figure 3. The contemporary Northeast Decision Support System for the northeastern conservation focal region in Nebraska. Decision support system values range from 2.50 to 100.00, indicating that areas exist where the conservation community can reach all objectives outlined in the criteria.

The resulting scenario-based DSS had values ranging from 6.25 to 81.25 (Figure 4). By converting 30% of the existing row crop agriculture to grassland, large tracts of land in Antelope and Boone counties were indicated as having a high likelihood of achieving multiple objectives. Cherry and Boyd counties were the least promising, containing values mostly below 25.00. This result is likely due to the limited amount of row crop agriculture in Cherry or Boyd counties compared to counties further east. Since the American burying beetle was not included in the scenario-based decision support system, the contemporary predicted presence locations are indicated by the purple border in Figure 4.

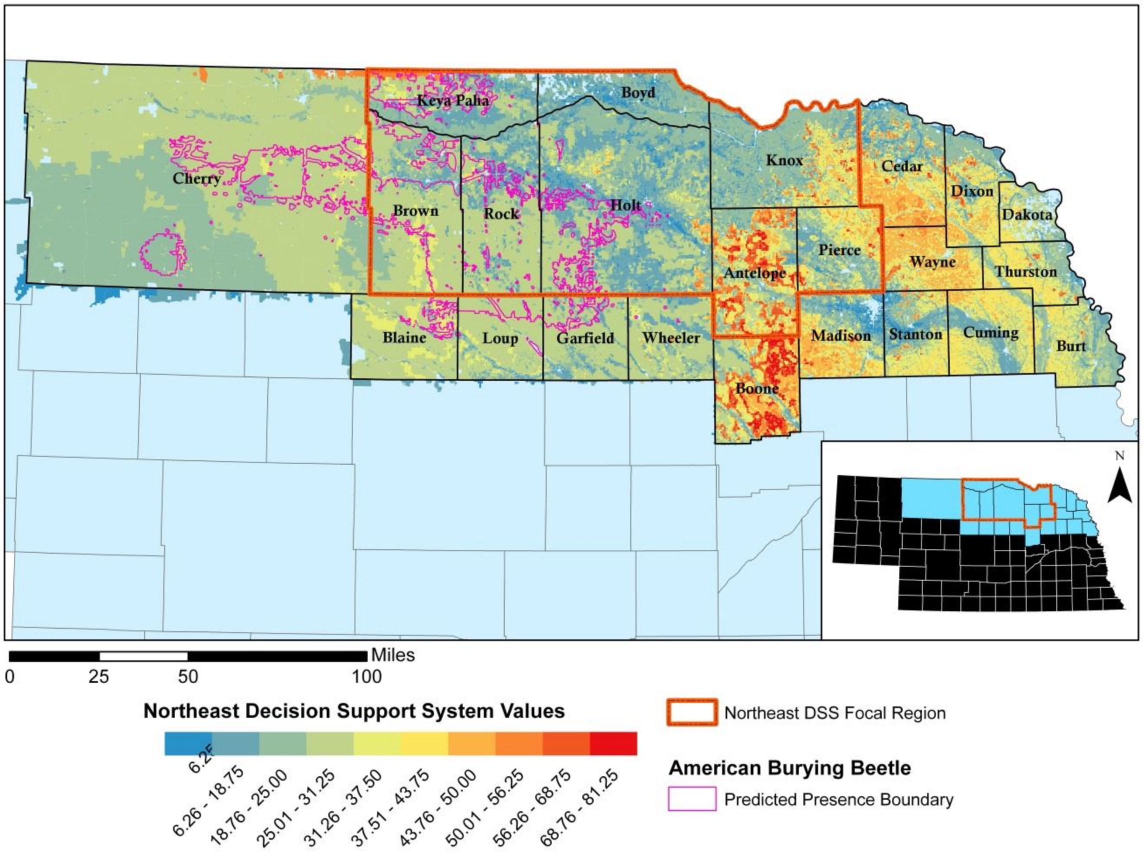

Figure 4. The scenario-based Northeast Decision Support System for the northeastern conservation focal region in Nebraska. Decision support system values range from 6.25 to 81.25, indicating that areas in Antelope and Boone counties have the highest likelihood of achieving conservation objectives based on the scenario of converting 30% of the surrounding row crop to grassland.

DISCUSSION

In the face of the compounded effects of a changing climate, exponential human population growth, and accelerated land-use change, implementation of effective conservation measures grows ever more challenging, as conservation organizations are often faced with limited funding and resources. Given the complexity of managing for multiple species, each inhabiting various local habitat types, it is astonishing that we can pinpoint specific areas and tracts of land within the focus area where conservation measures would benefit all species (Figure 3). Here we demonstrate the usefulness of decision support systems in aiding policymakers and habitat managers in making decisions about where to implement conservation programs, which may be particularly beneficial when federally endangered and at-risk species are in the mix. Although many tools have recently been developed to pinpoint where suitable habitat or species occur (Donald et al. 2002; Peterson 2003; Thomas et al. 2004; Hannah & Phillips 2004; Ficetola et al. 2007; McRae and Beier 2007; Niemuth et al. 2007; Franklin 2009), few studies address the benefits of using multiple spatially explicit models to help guide conservation decisions. Within the northeastern conservation focus region in Nebraska, conservation practitioners can use the contemporary DSS to detect regions where grassland conservation could benefit many priority species, in addition to the scenario-based DSS model, which can help identify land tracts best suited for future grassland conservation programs.

Though it is sometimes challenging to achieve multiple conservation objectives, particularly when multiple stakeholders are involved, the weighting system defined in the DSS criteria can be altered according to priorities or specific regions. For example, if a stakeholder group decided that Ring-necked Pheasants were a priority management concern, the group could adjust the weights within the scenario-based DSS. So, if pheasants accounted for 85% of the total weight in the DSS criteria, the resulting spatially explicit model would be highly weighted in favor of pheasant management and could help pinpoint tracts of land that have the highest likelihood of increasing pheasant populations, based on the surrounding landscape (Figure 5). Although pheasants may not be a conservation concern, this example can also be applied to Tier I at-risk species in Nebraska (Schneider et al. 2011), such as the American burying beetle.

Furthermore, having the ability to rank priorities as a stakeholder group can help facilitate the structured decision-making process and achieve an outcome on which all parties can agree.

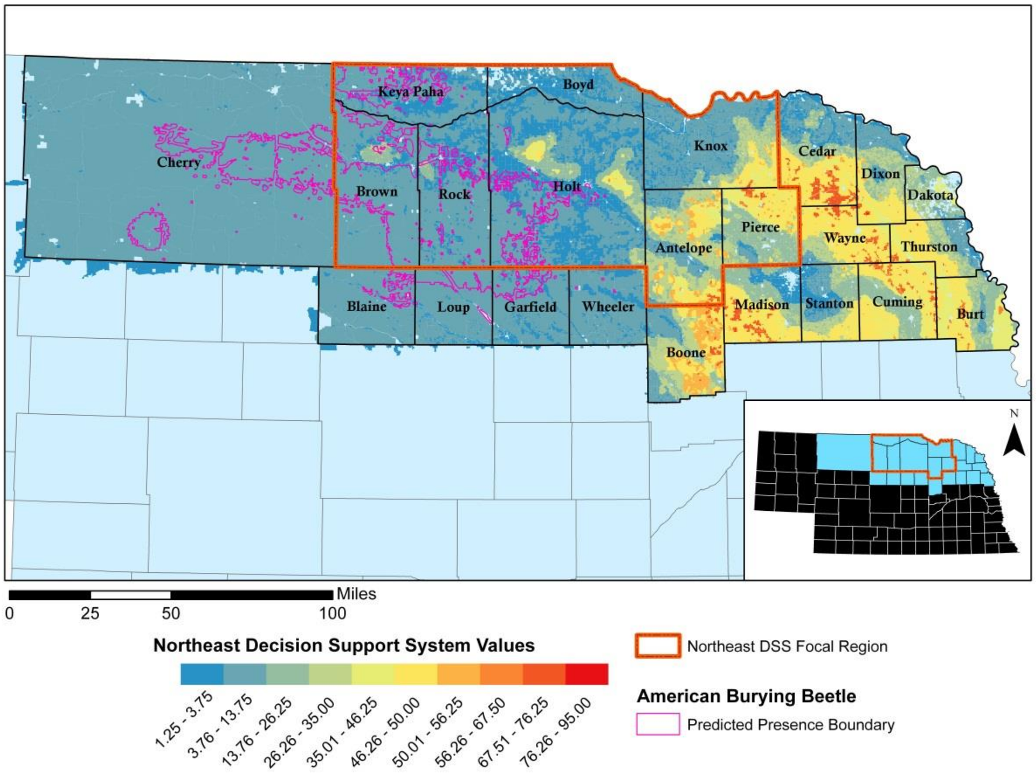

Figure 5. An example of the scenario-based Northeast Decision Support System for Nebraska, where the weighting criteria have been heavily adjusted in favor of Ring-necked Pheasants. Ring-necked Pheasants were assigned 85% of the criteria weight, while the remaining three factors in the decision support system were assigned 5%. The majority of the elevated decision support system values displayed represent landscapes best suited to support Ring-necked Pheasants after establishing new grassland.

REFERENCES

Best, L.B., Bergin, T.M., Freemark, K.E. 2001. Influence of landscape composition on bird use of row crop fields. *The Journal of Wildlife Management* 65: 442-449.

Bishop, A., Grosse, R., Nugent E., and Jorgensen C. 2012. Assessing Species Probability of Occurrence and Distribution for Greater Prairie Chicken, Sharp-tailed Grouse, and Long-billed Curlews Throughout Nebraska. Rainwater Basin Joint Venture. http://rwbjv.org/rainwater2012/wp-content/uploads/2013/04/Assessing-Species-Occurrence-Prairie-Grouse-and-LB-Curlew.pdf

Bollinger, E.K. and T.A. Gavin. 1992. Eastern Bobolink populations: ecology and conservation in an agricultural landscape. Pages 497-506 *in* Ecology and conservation of neotropical migrant landbirds. (Hagan III, J. M. and D. W. Johnston, Eds.) Smithson. Inst. Press, Washington, D.C.

Cain, Z., and Lovejoy, S. 2004. History and outlook for Farm Bill conservation programs. *Choices* 19:37-42.

Caro, T., Engilis, A., Jr., Fitzherbert, E., and Gardner, T. 2004. Preliminary assessment of the flagship species concept at a small scale. *Animal Conservation* 7:63-70.

Caro, T. 2010. Conservation by proxy: Indicator, umbrella, keystone, flagship and other surrogate species. Island Press, Washington, DC. 374p

Carroll, C., Noss, R.F. and Paquet, P.C. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. *Ecological Applications* 11:961-980.

Carey, M., D.E. Burhans and D.A. Nelson. 2008. Field Sparrow (Spizella pusilla), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/103

Cunningham, M.A., Johnson, D.H. 2006. Proximate and landscape factors influencing grassland bird distributions. *Ecological Applications* 16: 1062-1075.

Davis, S.K. and Lanyon, W.E. 2008. Western Meadowlark (Sturnella neglecta), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/104

DeFries, R.S., Foley, J.A., and Asner, G.P. 2004. Land-use choices: balancing human needs and ecosystem function. *Frontiers in Ecology and the Environment* 2: 249-257.

Donald, P.F., Pisano, G., Rayment, M.D., and Pain, D.J. 2002. The common agricultural policy, EU enlargement and conservation of Europe's farmland birds. *Agriculture Ecosystems and Environment* 89:167-182.

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. *The Journal of Wildlife Management* 61: 603-610.

Ficetola, G.F., Thuiller, W., and Miaud, C. 2007. Prediction and validation of the potential global distribution of a problematic alien invasive species – the American Bullfrog. *Diversity and Distributions* 13:476-485.

Fletcher, R.J., Jr., Yong, J.S., Hutto, R.L., Noson, A., and Rota, C.T. 2010. Insights from ecological theory on temporal dynamics and species distribution modeling. In: Drew, C.A., Wiersma, Y.F. and Huettmann, F. (eds), Predictive modeling in landscape ecology. Springer, New York, U.S.A.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., and Snyder, P.K. 2005. Global consequences of land use. *Science* 309: 570-574.

Franklin, J. 1995. Predictive vegetation mapping; geographic modeling of biospatial patterns in relation to environmental gradients. *Progress in Physical Geography* 19:474-499.

Franklin, J. 2009. Mapping Species Distributions: Spatial Inference and Prediction. Cambridge: Cambridge University Press. 336 p.

Fraser, S.E., Beresford, A.E., Peters, J., Redhead, J.W., Welch, A.J., et al. 2008. Effectiveness of vegetation surrogates for parasitoid wasps in reserve selection. Conserv Biol 23: 142–150.

Freeman, E.A. & Moison, G.G. 2008. PresenceAbsence: An R package for presence-absence model analysis. Journal of Statistical Software 23, 1-31. <http://www.jstatsoft.org/v23/i11> Accessed January 9, 2014.

Geisser, S. 1993. Predictive Inference. Chapman and Hall. New York, New York, USA.

Giudice, J.H., and Haroldson, K.J. 2007. Using regional wildlife surveys to assess the CRP: scale and data –quality issues. *Journal of Field Ornithology* 78: 140-151.

Groombridge, B. 1992. Global diversity: state of the earth’s living resources. Chapman & Hall, New York, U.S.A.

Guisan, A., and Zimmermann, N.E. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling* 135:147-186.

Hannah, L., Phillips, G.F. 2004. Extinction-risk coverage is worth inaccuracies. *Nature* 430:141.

Herkert, J.R. 2009. Response of bird populations to farmland set-aside programs. *Conservation Biology* 23: 1036-1040.

Hilden, O. 1965. Habitat selection in birds. *Ann. Zool. Fenn* 2: 53-75.

Hirzel, A.H. and Le Lay, G. 2008. Habitat suitability modeling and niche theory. *Journal of Applied Ecology* 45:1372-1381.

Holland, J.D., Bert, D.G., Fahrig, L. 2004. Determining the spatial scale of species’ response to habitat. *BioScience* 54: 227-233.

Holling, C.S. 1992. Cross-Scale Morphology, Geometry, and Dynamics of Ecosystems. *Ecological Monographs* 62: 447-502.

Hutto, R. L. 1985. Habitat selection by nonbreeding, migratory land birds. Pp. 455-476 in M. L. Cody (ed.) Habitat selection in birds. Academic Press, Inc., Orlando.

Jankowski, P., and Richard, L. 1994. Integration of GIS-based suitability analysis and multicriteria evaluation in a spatial decision support system for route selection. *Environment and Planning* 21: 323-323.

Jorgensen, C.F. 2012. Assessing local and landscape constraints on habitat management for grassland and upland birds. Thesis. University of Nebraska—Lincoln, Lincoln, Nebraska, USA.

Jorgensen, C.F., Bishop, A.A., Dudley, T., Grosse, R. and Nugent, E. 2013. Conservation of avian resources through species distribution models and strategic habitat conservation. Rainwater Basin Joint Venture Report, Grand Island, NE, U.S.A. <http://rwbjv.org/rainwater2012/wp-content/uploads/2013/09/Conservation-of-Avian-Resources-through-Species-Distribution-Models-and-Strategic-Habitat-Conservation.pdf>.

Jorgensen, C.F., McPherron, M., Jurzenski, J.D., Grosse, R., Bishop, A., Fritz, M., Harms, R., Koch, M., and Hoback, W.W. 2014*a*. Nebraska's American burying beetle Species Distribution Model for the Loess Prairie ecosystem. Rainwater Basin Joint Venture Report, Grand Island, Nebraska, U.S.A.

Jorgensen, C.F., Powell, L.A., Lusk, J.J., Bishop, A.A., Fontaine, J.J. 2014*b*. Assessing Landscape Constraints on Species Abundance: Does the Neighborhood Limit Species Response to Local Habitat Conservation Programs? PLoS ONE 9: e99339.

Jurzenski, J.D., Jorgensen, C.F., Bishop, A., Grosse, R., Riens, J., and Hoback, W.W. 2014. Identifying priority conservation areas for the American burying beetle, *Nicrophorus americanus* (Coleoptera: Silphidae), a habitat generalist. *Systematics and Biodiversity*

Kohavi, R. 1995. A study of cross-validation and bootstrap for accuracy estimation and model selection. *International Joint Conference On Artificial Intelligence* 14: 1137-1145.

Lindenmayer, D. B., & Fischer, J. 2006. Habitat fragmentation and landscape change: An ecological and conservation synthesis. Island Press. Washington, DC, U.S.A.

Lindenmayer, D.B., Barton, P.S., Lane, P.W., Westgate, M.J., McBurney, L., et al. 2014. An Empirical Assessment and Comparison of Species-Based and Habitat-Based Surrogates: A Case Study of Forest Vertebrates and Large Old Trees. PLoS ONE 9: e89807.

McRae, B.H., and Beier, P. 2007. Circuit theory predicts gene flow in plant and animal populations. *Proceedings of the National Academy of Sciences USA* 104:19885-19190.

McCoy, T.D., Ryan, M.R., Kurzejeski, E.W., Burger, L.W. Jr. 1999. Conservation Reserve Program: Source or sink habitat for grassland birds in Missouri? *The Journal of Wildlife Management* 63: 530-538.

Midgley, G.F., Hannah, L., Millar,D., Rutherford, M.C., and Powrie, L.W. 2002. Assessing the vulnerability of species richness to anthropogenic climate change in a biodiversity hotspot. *Global Ecology and Biogeography* 11:445-451.

Mistry, J., Berardi, A., Simpson, M. 2008. Birds as indicators of wetland status and change in the North Rupunini, Guyana. Biodivers Conserv 17:2383–2409.

Nielson, R.M., McDonald, L.L., Sullivan, J.P., Burgess, C., Johnson, D.S., Johnson, D.H., Bucholtz, S., Hyberg, S., and Howlin, S. 2008. Estimating the response of Ring-necked Pheasants (Phasianus colchicus) to the conservation reserve program. *The Auk* 125: 434-444.

Niemuth N.D., Quamen, F.R., Naugle, D.E., Reynolds, R.E., Estey, M.E., and Shaffer, T.L. 2007. Benefits of the Conservation Reserve Program to Grassland Bird Populations in the Prairie Pothole Region of North Dakota and South Dakota. Report prepared for the US Department of Agriculture Farm Service Agency. RFA OS-IA-04000000-N34. (27 July 2009; http://www.fsa.usda.gov/Internet/FSA_File/grassland_birds_fws.pdf)

Patz, J.A., Daszak, P., Tabor, G.M., Aguirre, A.A., Pearl, M., Epstein, J., and Working Group on Land Use Change Disease Emergence. 2004. Unhealthy landscapes: policy recommendations on land use change and infectious disease emergence. *Environmental health perspectives* 112: 1092.

Peterjohn, B.G. and D.L. Rice. 1991. The Ohio breeding bird atlas. Ohio Dep. Nat. Resour. Columbus.

Peterjohn, B.G. 2003. Agricultural landscapes: Can they support healthy bird populations as well as farm products? *The Auk* 120: 14-19.

Peters, R.H. 1983. The ecological implications of body size. Cambridge: Cambridge University Press. 344 p.

Peterson, A.T. 2003. Predicting the geography of species' invasions via ecological niche modeling. *The Quarterly Review of Biology* 78:419-433.

Ponder, W.F., Carter, G.A., Flemons, P., and Chapman, R.R. 2001. Evaluation of museum collection data for use in biodiversity assessment. *Conservation Biology* 15:648-657.

Rahmig, C.J., Jensen, W.E., and With, K.A. 2008 Grassland bird responses to land management in the largest remaining tallgrass prairie. *Conservation Biology* 23: 420-432.

Rodgers, R.D. 1999. Why haven't Pheasant populations in western Kansas increased with CRP? *Wildlife Society Bulletin* 27: 654-665.

Rosenzwieg, M.L. 1991. Habitat selection and population interactions: The search for mechanism. *The American Naturalist* 137: S5-S28.

Royle, J.A. 2004. N-Mixture Models for Estimating Population Size from Spatially Replicated Counts. *Biometrics* 60:108-115.

Saab, V. 1999 Importance of spatial scale to habitat use by breeding birds in riparian forests: A hierarchical analysis. *Ecological Applications* 9: 135-151.

Saha, J.J., and Haldar, P. 2009. Acridids as indicators of disturbance in dry deciduous forest of West Bengal in India. Biodivers Conserv 18:2343–2350.

Schneider, R., Stoner, K., Steinauer, G., Panella, M., and Humpert, M. 2011. The Nebraska Natural Legacy Project: State wildlife action plan, 2nd edition. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

Stephens, S.E., Koons, D.N., Rotella, J.J., and Willey, D.W. 2003. Effects of habitat fragmentation on avian nesting success: A review of the evidence at multiple spatial scales. *Biological Conservation* 115**:**101-110

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2014. *The North American Breeding Bird Survey, Results and Analysis 1966 - 2012. Version 02.19.2014 USGS Patuxent Wildlife Research Center, Laurel, MD*

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., Ferraria de Siqueira, M., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsvels, A.S., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Peterson, A.T., Phillips, O.L., and Williams, S.E. 2004. Extinction risk from climate change. *Nature* 427:145-148.

Thuiller, W. 2007. Biodiversity: climate change and the ecologist. *Nature* 448: 550-552.

U.S. Fish and Wildlife Service. 2012. Draft guidance on selecting species for design of landscape-scale conservation. U.S. Fish and Wildlife Service Unpublished Report. <http://www.fws.gov/landscape-conservation/pdf/DraftTechnicalGuidanceJuly2012.pdf>, accessed May 2nd, 2014.

U.S. Department of Agriculture. 1978. Predicting rainfall erosion losses: A guide to conservation planning. U.S. Department of Agriculture, Agriculture Handbook 537.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2011. SSURGO soil data. Available online at <http://soildatamart.nrcs.usda.gov>

U.S. Department of Agriculture, Natural Resources Conservation Service. 2012. Conservation Reserve Program. Available online <http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp>

U.S. Department of Agriculture, Farm Service Agency. 2013. What is a Common Land Unit? Available online <http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prod&topic=clu>

Verbyla, D.L., & Litvaitis, J.A. 1989. Resampling methods for evaluation classification accuracy of wildlife habitat models. *Environmental Management* 13: 783-787.

Vickery, P.D. 1996. Grasshopper Sparrow (Ammodramus savannarum), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/239

Wiens, J.A. 1994. Habitat fragmentation: Island v landscape perspectives on bird conservation. *Ibis* 137:S97-S104.

Woodruff, N.P., and Siddoway, F.H. 1965. A Wind Erosion Equation. *Soil Science Society of America Proceedings* 29:602-608.

Zhu, L., Sun, O.J., Sang, W., Li, Z., and Ma, K. 2007. Predicting the spatial distribution of an invasive plant species (*Eupatorium adenophorum*) in China. *Landscape Ecology* 22:1143-1154.

Zuur, A.F., Ieno, E.N. & Smith, G.M. 2007. Analyzing ecological data. Springer, New York, New York, USA.